Permanent Damage Effects in Optocouplers and LEDs

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Permanent Damage in Optocouplers and LEDs

Light-Emitting Diodes

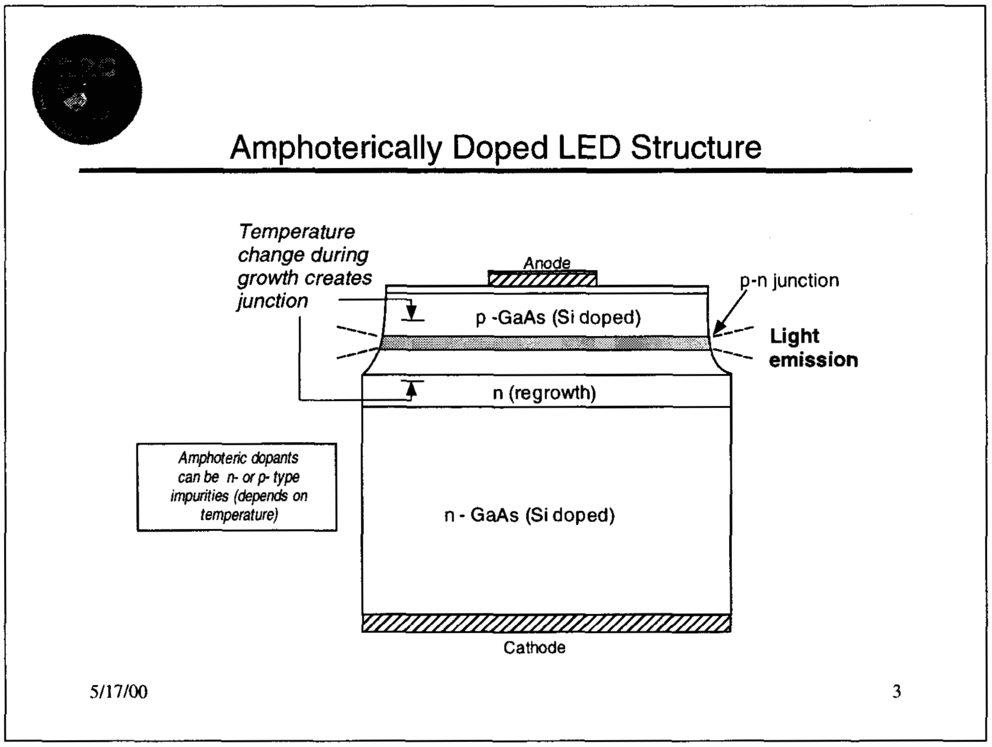
- Extremely sensitive to displacement damage effects
- Uncertainty about energy dependence of proton damage
- Annealing, variability affect results

Wide Variety of LEDs Investigated

- High-efficiency amphoterically doped devices
- Newer device types with double-heterojunction structures

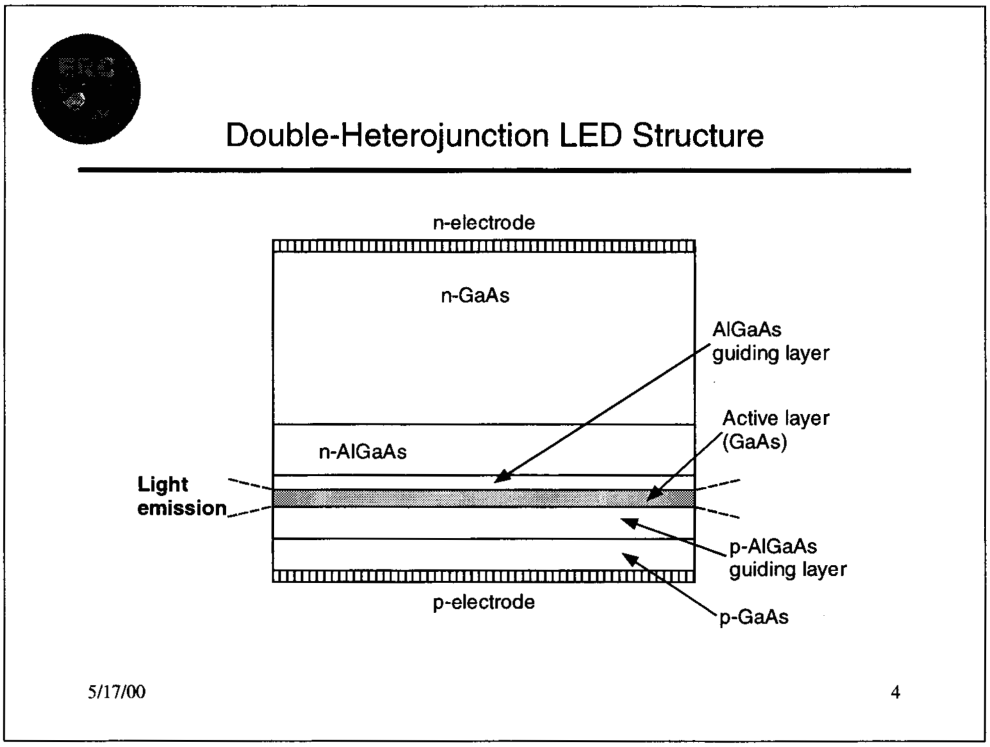
LED Wearout Is a Significant Issue

- Decreases light output over time
- May be additive to radiation damage



This slide shows a diagram of an amphoterically doped LED. The junction is formed by gradually changing the temperature of the upper layer as it is grown during the fabrication cycle. The effect type of the dopant shifts when the temperature reaches a critical temperature. This allows an LED to be fabricated with only a single dopant.

Amphtoerically dped LEDs are very efficient, and provide higher light output than LEDs fabricated with other processes. Even though this is a very old process, it is still widely used to fabricate LEDs with wavelengths between 850 and 930 nm.



This slide shows a more modern LED that is made with an advanced process using two heterojunctions. The heterojunctions allow very efficient carrier injection into the center GaAs region where most of the light is produced.

The fabrication processes for this type of LED are much more complex, requiring careful control of very thin regions with different compositions. Double-heterojunciton LEDs can be affected by defects during the growth of different material types.

LEDs Selected for Radiation Testing

Type	Wavelength (nm)	Manufacturer	Technology
L3882	660	Hamamatsu	Diffused
OD800	810	Optodiode	Double-heterojunction
L7558	830	Hamamastsu	Double-heterojunction
L3989	850	Hamamatsu	Double-heterojunction
OP233	870	Optek	Amphoteric
OD880	880	Optodiode	Amphoteric
OP130	930	Optek	Amphoteric
LST0400	1300	Agilent Tech.	Double-heterojunction

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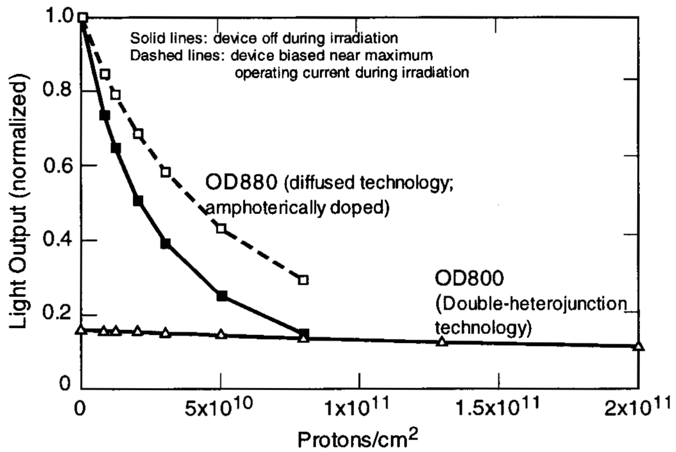
This slide lists the types of LEDs that were selected for radiation testing. There is a wide range of wavelengths, representing several different types of LEDs from a number of manufacturers.

Degradation of Amphoteric and DH LEDs



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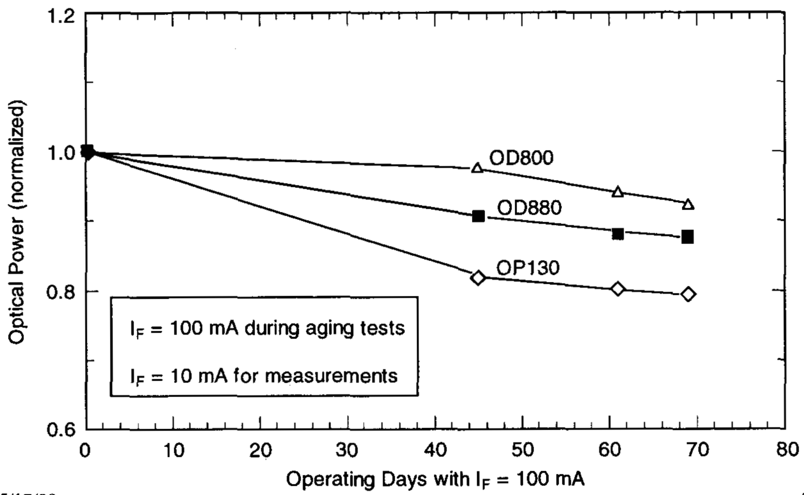
This slide compares degradation of two different LED technologies from the same manufacturer. Although the double-heterojunction device is much less affected by radiation, the initial light output is much lower. This tradeoff is required when one selects LEDs for various applications. Amphoterically doped LEDs can be used in space as long as allowance is made for the more extreme degradation that occurs.

Effect of Operating Current on Optical Output Power



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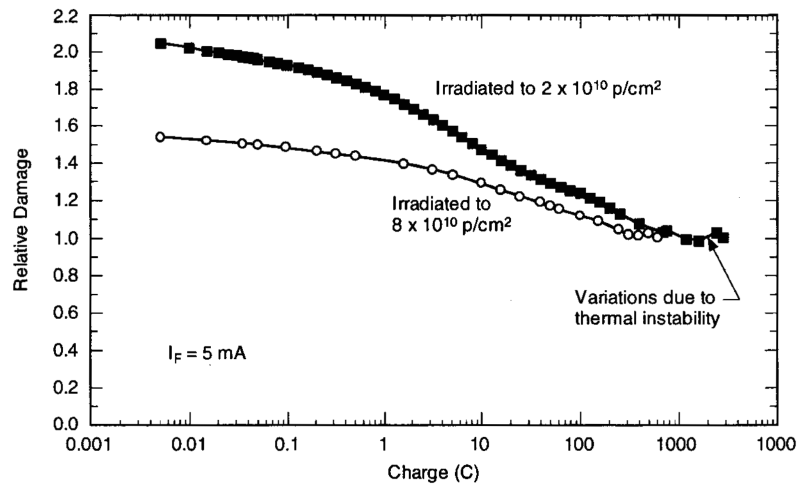
This slide shows how the light output of three different types of LEDs is affected by operation near their maximum rated output. Three is substantial loss in output after about 1000 hours.

Work is in progress to compare radiation degradation on "aged" samples with those from the same lot that have not been operated for extended periods in order to see if the radiation and aging degradation should be added together.

Injection-Enhanced Annealing of OP233 LED



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This slide shows how radiation damage in an irradiated LED is affected by the amount of charge that is passed through the device after irradiatkion. Although about 1/2 of the damage will eventually recover, it takes very long operating times unless the devices are used at very high currents, an unlikely scenario for space applications.

Work in Progress for LEDs and Optocouplers

Additional Proton Testing of LEDs
- Effects of aging on radiation response
- Damage linearity and modeling

Damage Variability
- Abnormal damage mechanisms
- Lot variability

Additional Work on Injection-Enhanced Annealing

Technical Paper Accepted for 2000 NSREC

LEDs in Optocouplers

Relationship between LED Work and Optocouplers

- LED damage often dominates optocoupler response
- Injection-enhanced annealing important in optocoupler characterization

Wide Variety of LEDs Are Used in Optocouplers

- Amphoterically doped LEDs (highest efficiency)
- Visible wavelength (diffused) LEDs
- Double-heterojunction LEDs

Limited Control of LEDs in Most Optocouplers

- Often purchased from outside vendors
- Wavelength not included in optocoupler specification

Failures of Optocouplers on Topex-Poseidon

High Inclination Orbit (1300 km)

Five Different Applications of a High-Reliability Optocoupler
- Optocouplers in thruster *status* circuit failed after 21/2 years in orbit
- Radiation level approximately 2×10^{10} p/cm^2

Optocouplers also Used in Thruster Control System
- Extreme concern about failure in that part of system
- On-board spares of little value
- More conservative design used in thruster control circuit

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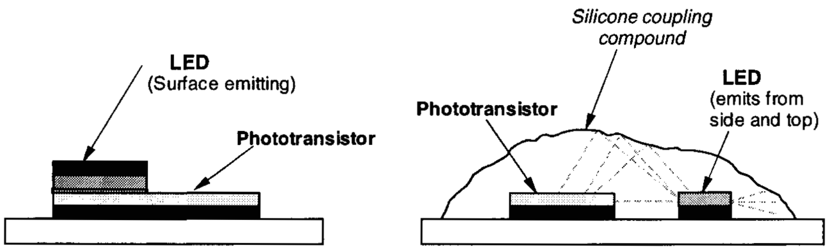
Two Configurations Used for Optocouplers



(a) Sandwich structure
(direct coupling to detector)

(b) Lateral structure
(reduced coupling efficiency)

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This slide shows the construction methods that are used for two different types of optocouplers. The direct coupling method places the LED assembly directly over the phototransistor, and provides more consistent light coupling. However, it is more costly to produce.

The indirect method relies on a silicone "cone" to couple light from the LED to the photodiode by total internal reflection. This coupling method is much easier to manufacture, but leads to wider unit-to-unit variability in performance because of the difficulty of controlling physical factors that affect the light coupling. The roughness of the LED facets and bubbles in the silicon are examples of physical factors that are important.

Digital and Linear Optocouplers

Digital Optocouplers

- Moderate speed, low input current devices
- High speed with high input current requirements
- Current transfer ratio varies over a broad range
- Wide range of LED technologies (660 to 930 nm wavelength)

Linear Optocouplers

- Requires control of current transfer ratio over narrow range
- Design "tricks" are used to lower sensitivity to temperature and other variable
- Any LED technology can be used

Remaining Issues

Design and Testing Standards for LEDs and Optocouplers

- Design margins
- Controlling wavelength and other critical design issues
- Derating factors for temperature and wearout
- Annealing
- Energy dependence of damage

Screening Methods

- Devices with abnormal characteristics
  - Coupling problems
  - LEDs with excessive recombination losses
- Limiting unit-to-unit variability

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Summary and Status of Work

LED Technology Investigation Nearing Completion

- Wide range of designs and characteristics
- Damage linearity and temperature dependence vary
- Wearout investigation in progress

Test Standards for Optocouplers Are Planned for Next Quarter

- Incorporates results from JPL and GSFC
- Energy dependence study in progress at GSFC
  - Paper at 2000 NSREC
  - Important issue for test standards and data interpretation